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## Spectral Gamma-Ray Logging Report for the 216-B-57 Crib Groundwater Impact Assessment

**G. J. Schwartz**

Westinghouse Hanford Company, Richland, WA 99352

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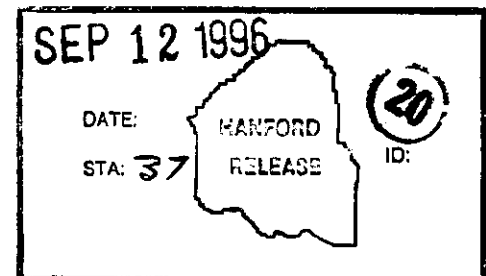
**Abstract:** Using the In Situ Characterization Probe to place access holes near the 216-B-57 Crib, the Radionuclide Logging System was used to further characterize the radioelement contamination surrounding the crib. Data collection was not completely successful in that the logging sonde was not able to go the full depth of each of the access holes. However, significant data were gathered and analyzed to meet the objective of the effort.

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## CONTENTS

1.0 INTRODUCTION .....	1
2.0 SITE SETTING .....	2
2.1 GEOGRAPHY .....	2
2.2 GEOLOGY .....	2
2.3 HISTORY .....	6
3.0 THE SURVEY DATA .....	7
4.0 CONCLUSIONS .....	8
5.0 FUTURE CONSIDERATIONS .....	9
6.0 REFERENCES .....	10

## FIGURES

1. 200-BP-1 Operable Unit .....	3
2. Well Locations Characterizing Crib 216-B-57 .....	4
3. 216-B-57 Crib Cross-Section and Well Sample Intervals .....	5

**TABLES**

1. Selected 200-BP-1 Physical Properties, Crib 216-B-57A .....	6
2. Summary of Maximum Radionuclide Depths from RLS Log Surveys of B-57 In-Situ Characterization Holes .....	8
3. Anthropogenic Radionuclide Detection Intervals and Activity Levels .....	8

**APPENDICES**

A Radionuclide Logging System (RLS) Data for In-situ Characterization Hole GP-5 .....	A-1
B RLS Survey Data .....	B-1
C RLS Data for Other Holes in the Vicinity of Crib 216-B-57 .....	C-1
D The RLS System, It's Data and Data Analysis Limitations .....	D-1

## **SPECTRAL GAMMA-RAY LOGGING REPORT FOR THE 216-B-57 CRIB GROUNDWATER IMPACT ASSESSMENT**

### **1.0 INTRODUCTION**

Characterization boreholes were drilled through The B-57 Crib in 1991, samples taken and analyzed, and the Radionuclide Logging System (RLS) was used to geophysical log the boreholes to assay the quantities of anthropogenic (man-made) radioisotopes surrounding the boreholes. (The RLS is a high-resolution, high-purity germanium (HPGe), passive, spectral gamma-ray detection system that measures subsurface gamma-ray radiation intensity and its vertical distribution.)

As a continuation to that program and to further assess the extent of the radioactive contamination around the 216-B-57 Crib, four additional subsurface access holes were constructed so that additional radionuclide concentration data could be collected with the RLS and used to again assay the radioisotopes around the access holes, or ports, in the vicinity of the crib to aide in the subsurface characterization of the 216-B-57 Crib. The RLS data will be used to define the maximum horizontal extent of the subsurface contamination. Contamination was detected in only three of the four holes, two at near-surface and one (GP-9) at a depth of 33 ft.

These access holes have been designated "In Situ Characterization Probe Subsurface Access Holes: GP-6, GP-7, GP-9 & GP-9" and were constructed with the "In Situ Characterization Probe", a diesel-powered, pile-driving machine used to drive down to "depth" 4- or 5-inch drill string with a cone mounted on the first string.

The contents of this report are limited to the description of the survey results for each access hole logged. A description and details of the RLS System and how it worked in this project and the limitations to radioelement analysis are contained in Appendix D. It is strongly recommended that readers unfamiliar with this very sophisticated, state-of-the-art logging system refer to this appendix, and they are urged to peruse it for pertinent information to familiarized themselves with its detailed capabilities and limitation.

Details of equipment configuration, calibration, logging procedures, casing and water correction factors, spectral analysis software, and data management have been excluded from this report. The details of these topics are described in the papers cited.

## 2.0 SITE SETTING

### 2.1 GEOGRAPHY

The 216-B-57 Crib is one of ten inactive cribs within the 200-BP-1 Operable Unit (Figure 1). The operable unit was also the site of four unplanned releases.

To date there have been at least nine boreholes constructed within 100 ft of the 216-B-57 Crib boundaries, as defined by engineering drawings. Three of these boreholes (299-E33-304, 299-E33-305, and 299-E33-306) were drilled through the crib in three locations for sample retrieval and geophysical logging. They have since been plugged and abandoned. Also a groundwater well (299-E33-24) is in place just to the west side of the crib, Figure 2.

A total of five In Situ Characterization Probe holes (GP-5, GP-6, GP-7, GP-8, and GP-9) were installed to characterize the horizontal extent of the radioactive contamination. All boreholes and adjacent probe locations can be found in Figure 2.

### 2.2 GEOLOGY

The 200-BP-1 Operable Unit is situated at an average elevation of approximately 192 meters (630 ft) above mean sea level on the Cold Creek flood bar (Bretz et.al., 1956). The geologic units of interest found in the vicinity of the 200-BP-1 Operable Unit include from oldest to youngest: (1) the Ringold Formation, (2) the Hanford formation, and (3) the Holocene surficial deposits. B-57 Crib site data were taken in boreholes 299-E33-304, -305, and -306; initially identified as 216-B-57A, -57B, and -57C. Three holes were split-spoon sampled and geologically logged from drill collar to hole bottom. Well summary sheets can be found in Hoffman, 1992 (WHC-SD-EN-TI-054, Rev. 0). Figure 3 shows where the samples were collected for chemical analysis, as well as soil-gravel-soil interfaces. These samples reveal a porous and dry subsurface.

Selected physical properties of the 216-B-57A borehole are presented below in Table 1. This data is provided to establish the hypothesis that horizontal migration of contamination will be limited due to the high porosity and low saturation of the gravel/sand subsurface. For more information see WHC-SD-EN-TI-054, Rev 0.

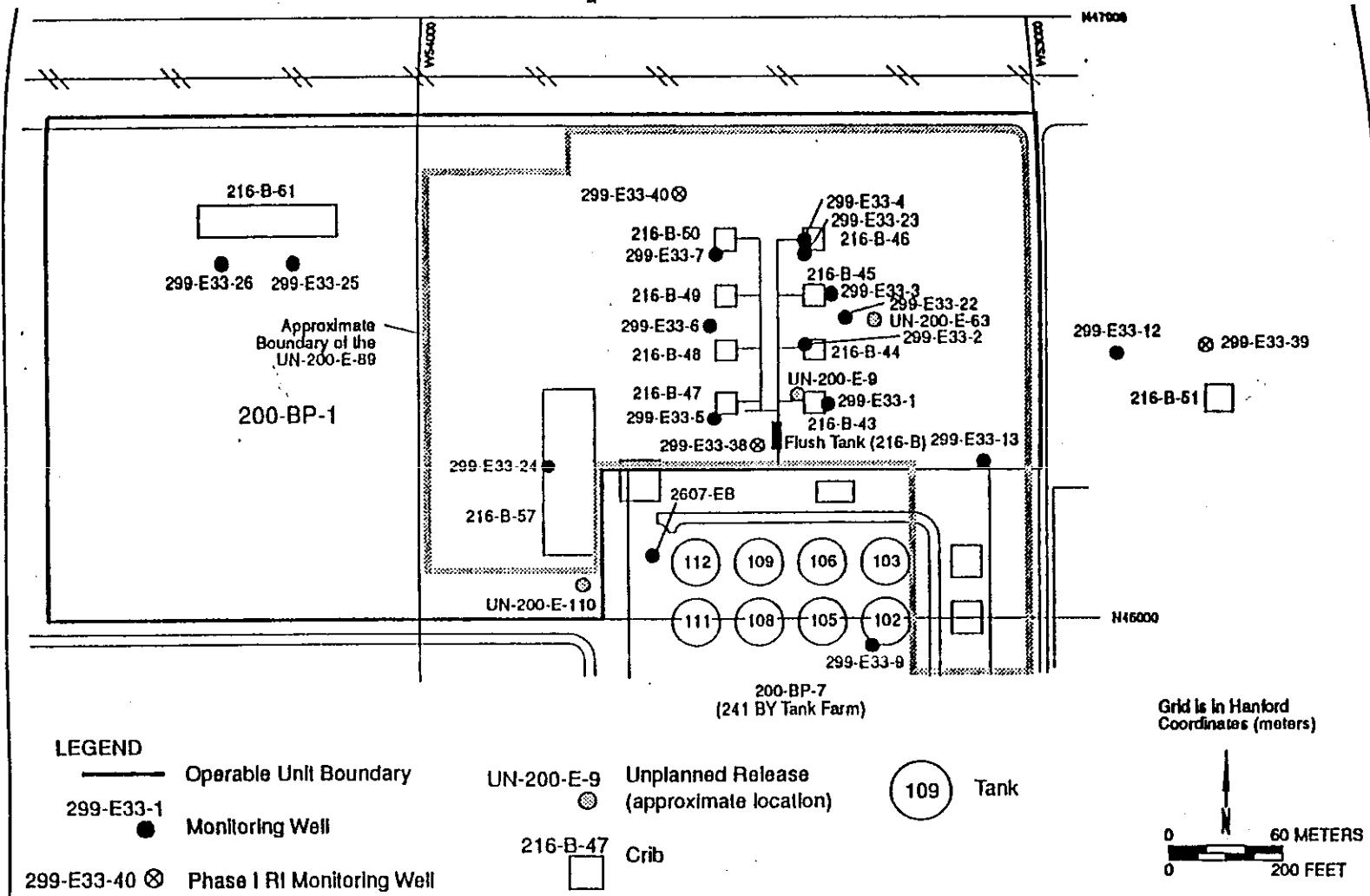
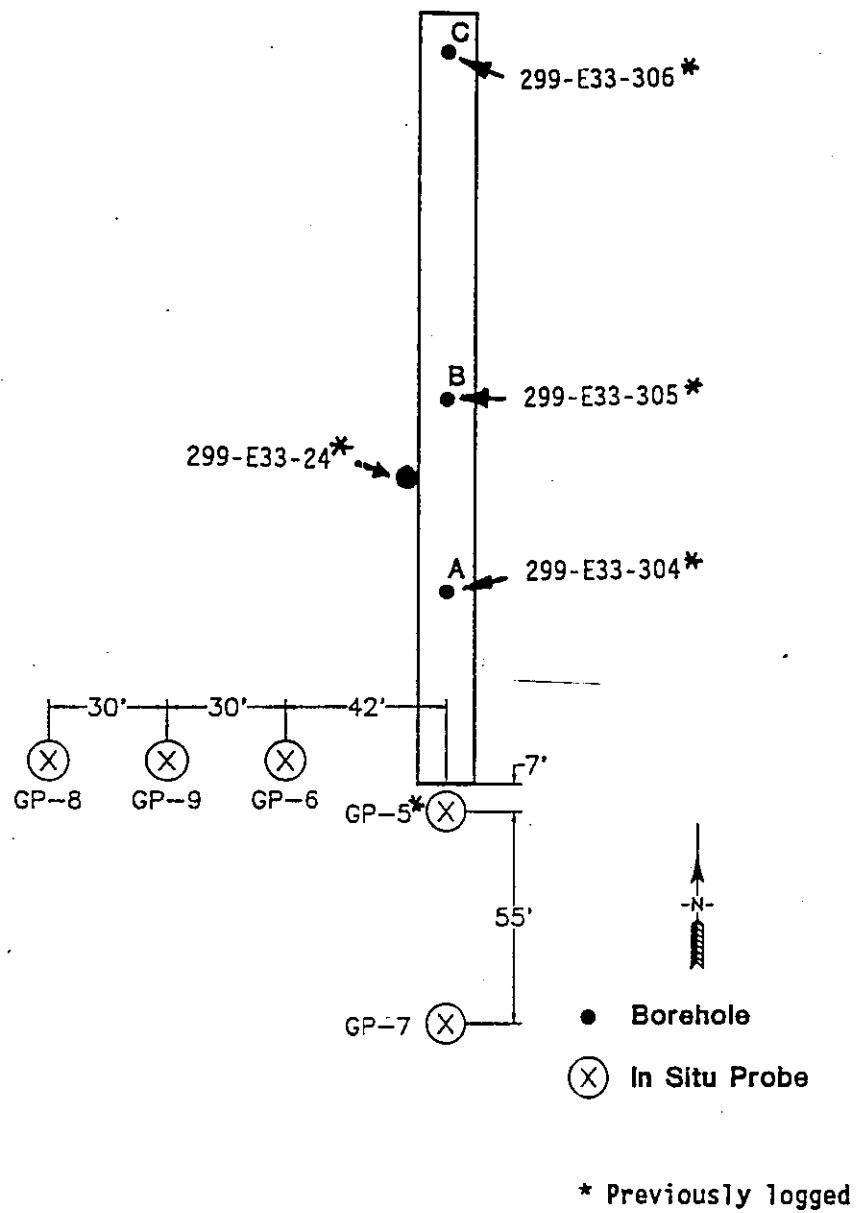


Figure 2: Well Locations Characterizing Crib 216-B-57





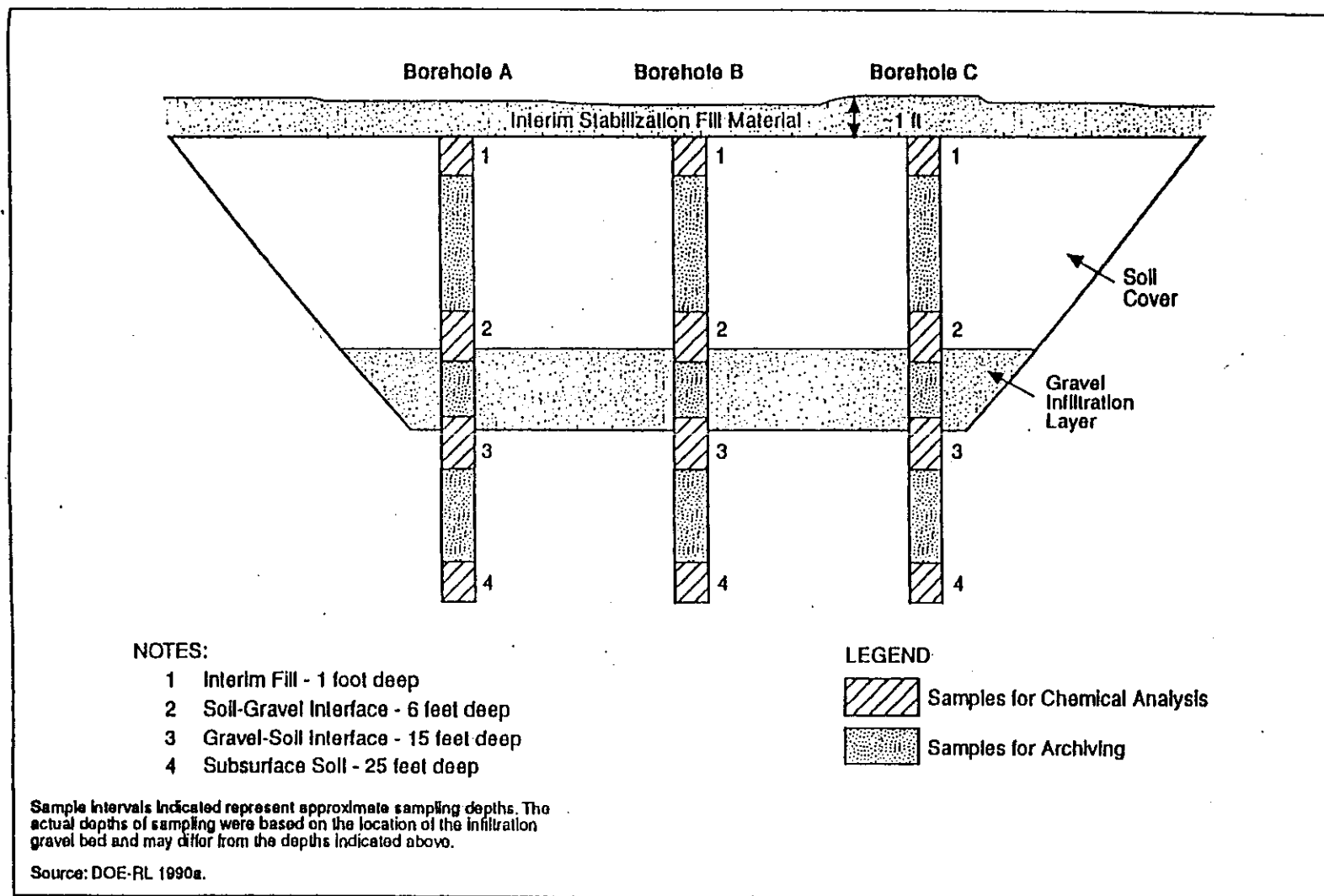


Figure 3: 216-B-57 Crib Cross-Section and Well Sample Intervals

**Table 1. Selected 200-BP-1 Physical Properties****CRIB 216-B-57A**

<b>Footage (ft) Below Surface</b>	<b>Moisture (wt%)</b>	<b>Porosity (%)</b>	<b>Specific Gravity</b>
15.0	2.60	23.89	2.74
26.0	3.18	25.46	2.66
40.5	1.71	38.06	2.71
48.0	2.22	35.79	2.68

**2.3 HISTORY**

The 216-B-57 Crib received in-tank solidification (ITS) condensates that were low-level wastes. These ITS waste streams were considered suitable for crib disposal and vadose infiltration in large volumes.

An as-built drawing for crib 216-B-57 (WHC Drawing H-2-78769, Rev. 0) in DOE/RL, 1990 indicates that the crib consists of a 30.5-cm (12-in.) corrugated and perforated steel pipe that runs the length of the 61-m (200-ft) long and 4.6-m (15-ft) wide crib. The base of the 3-m (10-ft) deep excavation is level, and the pipe within it dips down from the South to the North. The crib bottom is covered with gravel to a depth of 1.2 m (4 ft) with the remainder of the crib filled with sandy soil (Figure 3). Side slopes are 1.5:1.

As discussed earlier and identified on Figure 2, RLS logging surveys were previously acquired in boreholes: 299-E33-304 (233 ft total depth (TD)), 299-E33-305 (50 ft TD), 299-E33-306 (50 ft TD), 299-E33-24 (249.7 ft TD), and in the In-Situ Characterization Hole GP-5 (47 ft TD). Holes 299-E33-304, 299-E33-305, and GP-5 showed gamma radiation from a man-made source (cesium-137). Gamma-ray radiation from man-made sources was not detected in borehole 299-E33-306. For complete RLS logging results of GP-5 and the four in situ access holes, see Appendices A and B, respectively. The probe locations for GP-6 through GP-9 were selected largely due to the results of these previous surveys. Mostly, the probe locations were chosen to define the extent of the man-made radionuclide contamination and its horizontal migration.

### 3.0 THE SURVEY DATA

The tables in Appendix B entitled "RLS Spectral Gamma-Ray Borehole Survey Log Header" summarize the borehole and survey information. Plots of the total gamma-ray counts per second (Total Gamma) along with the calculated man-made isotope concentrations are presented on the page following the header. The "Total Gamma" is the count rate for all gamma rays detected by the RLS detector, with no discrimination of gamma-ray energy. The Total Gamma is equivalent to the gross gamma-ray log commonly used in the past at Hanford.

The plots of radionuclide-activity response versus depth are shown in Appendix B along with notes and a summary. On the plots of Appendix B, a uniform depth scale of 20 ft per inch, and a radionuclide-concentration scale of 40 pCi/g per inch are used. The experimental uncertainties in the computed radionuclide activities are not presented on the data plots at this time.

The decay activity for the natural radionuclides, potassium, uranium, and thorium, have been computed through the normal spectral analysis of the data reduction program and are presented, with the Total Gamma, on the page following the plots of the other data.

Long-count, stationary measurements of at least 300 seconds (shown as short bars in the plotted data and best seen in the plots of the potassium, uranium and thorium channels for access holes CP-6 at a depth of 12 ft and CP-9 at a depth of 32 ft) were recorded at some depth points (stations) in all holes to verify the validity of the data acquired with the 80-seconds-per-half-ft survey. Both the long and 80-second measurements were acquired at essentially some given common depth. The extended acquisition time did not identify additional radionuclides in any of these wells or in situ characterization holes.

Table 2, below, summarizes the maximum depths that man-made radionuclides were detected and differentiated by spectral analysis. Table 3 summarizes all intervals of man-made radionuclide detection and the maximum activity levels detected. The only man-made, gamma-ray-emitting radionuclide identified was cesium-137.

**Table 2. Summary of Maximum Radionuclide Depths from RLS Log Surveys of B-57 In-Situ Characterization Holes.**

Access Hole ID	Survey Date <sup>1</sup>	Borehole Depth	Survey Depth <sup>2</sup>	Cesium-137 Depth <sup>3</sup>
GP-6	03/05/93	48.88'	12.5'	-
GP-7	03/05/93	47.5'	43.5'	2'
GP-8	03/08/93	46.2'	18.5'	0.5'
GP-9	03/09/93	49.2'	46.5'	31-33'

<sup>1</sup>Date survey was completed<sup>2</sup>Maximum survey depth<sup>3</sup>Maximum depth where radionuclide was identified**Table 3. Anthropogenic Radionuclide Detection Intervals, and Activity Levels.**

Access Hole ID	Interval(s) of Cesium-137 Detection	Depth of Maximum Activity Detected	Maximum Cesium-137 Detected (pCi/g) <sup>1</sup>
GP-6	-	-	-
GP-7	0-2.0'	1.0'	4.0 pCi/g
GP-8	0-0.5'	surface	0.7 pCi/g
GP-9	31.0-33.0'	32.0'	3.0 pCi/g

<sup>1</sup>Picocuries per gram.

#### 4.0 CONCLUSIONS

The minor cesium-137 contamination in hole GP-9 at the depth interval of 31 to 33 ft is most likely a product of horizontal migration from the 216-B-57 Crib. In situ characterization holes GP-6 and GP-8 had too much curvature for the RLS tool to fit down hole to a depth of 30 ft. This limitation on survey depth prevented collecting data from these holes to confirm or deny the presence of cesium-137 at the 31- to 33-ft depth below the surface as detected in hole GP-9. (The Westinghouse Borehole Geophysics Group has since thinned the diameter of the tool, to lessen RLS limitations in the future.)

As seen in Appendix A, the results of data analysis of In Situ Characterization Hole GP-5 show there is abundant cesium-137 gamma-ray energy detected approximately 18 ft down. The proximity of GP-5 to the perforated pipe that feeds the crib supports the reasonableness of the high cesium-137 readings.

The geology of this site is characterized by the presence of "gravelly sand" with moisture less than 4% by weight and porosity no less than 24% (Buckmaster 1992). Based on this characterization, it is reasonable to assume that radionuclide travel in a horizontal direction would be limited, if not absent. The high activity of cesium-137 in hole GP-5, and the absence of cesium in GP-7 at, or around, a depth of 18 ft, may support the theory of minimal horizontal flow for radioactive contamination. Conversely, the presence of cesium-137 in access hole GP-9 (and the possibility of its presence in GP-6) would suggest minimal horizontal migration, but with a preferred direction.

## 5.0 FUTURE CONSIDERATIONS

The RLS gamma-ray logging probe can be made even thinner than the existing one. This smaller diameter would allow the tool to be used to log wells that have a down-hole radius of curvature too great to allow use of the present tool. Holes GP-6 and GP-8 were two such holes. Reducing the diameter of the RLS tool will be considered.

Spectral analysis of data from groundwater well 299-E33-24 indicates activity of man-made cobalt-60 from approximately 230-244 ft (Appendix C). Well 299-E33-05 is the next closest groundwater well to the 216-B-57 Crib, and it is part of the 216-B-47 Crib characterization. In the plot provided in Appendix C, well 299-E33-05 also shows cobalt-60 activity at a depth of approximately 225 to 233 ft. Wells in the area may be examined to attempt to characterize the cobalt-60 level in the groundwater. There are numerous wells in the area of crib 216-B-57 which can be studied comprehensively and simultaneously to determine the spacial relationship between detected man-made radionuclides and the distance from the perforated pipe in the crib. A geostatistical analysis of this spacial relationship may yield estimated concentrations of radionuclide contamination in three dimensions. However, this type of theoretical modelling is inappropriate at this time for the needs of the project and the effort required.

## 6.0 REFERENCES

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**APPENDIX A**

**RLS Data for In-Situ Characterization Hole GP-5**

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Westinghouse Hanford Company  
RLS Spectral Gamma-Ray Borehole Survey Log Header

Project: Cone Penetrometer Tech. Dev.

Borehole	<u>GP-5</u>		
Coordinates	<u>46153 N</u>	<u>53775 W</u>	ft (Plant 200 E)
Elevation	<u>          </u>	ft	Top of Casing (Plant 200 E)

Borehole Environment Information

Borehole Fluid Depth <u>none</u> (ft) from Zero (0.0) Depth Reference of Log			
Casing Size I.D. (in)	Casing Thickness (in)	Top Depth (ft)	Base Depth (ft)
4	0.26	0	47

RLS Passive Spectral Gamma Survey Information

Logging Engineers <u>R. V. Cram</u> <u>S. E. Kos</u>					
Log Depth Reference at Zero (0.0) depth is <u>Ground Level</u>					
Log Date	Archive File Names	Log Mode, Speed	Depth Interval (ft)		
			Top	Base	Incr
Sept 30, 92	GP05\A256	MSA 80sec LT	0	20	0.5
		MSA 80sec RT	20	24	0.5

MSA: Move-Stop-Acquire Lt: Live Time Rt: Real Time

Calibration and Analysis Information

RLS Calibration Date: Nov 21, 1991	
Calibration Report: WHC-SD-EN-TRP-001	
Analyst Names: <u>J. P. Kiesler</u>	
Analysis Date: <u>Oct 12, 1992</u>	
Analysis Notes: <u>Bend in casing restricted survey depth to 24 ft.</u>	
Radionuclides identified: <u>Cs-137</u>	

RLS Borehole Survey Report

GP-5 Cone Penetrometer

Casing	Depth: 47 ft	Size: 4"	Thickness: 0.26 in
Water	Depth: none		
Survey	Depth: 0 - 20 ft	Mode: MSA 80sec	
	20 - 24 ft	Mode: MSA 80sec Gated Integrator	

**General Notes:**

The hole was only logged to 24 feet, hole conditions would not permit the sonde to pass further down.

Log acquisition was switched from the standard counting configuration to Gated Integrator with 0.25  $\mu$ sec shaping when gross gamma activity approached 40,000 counts per second at 20 ft.

Gamma activity saturated the logging system from 21 feet to maximum survey depth of 24 feet.

**Man-made Radionuclides:**

Cesium (Cs-137) was encountered from 0 feet to 3 feet and 18 feet to 24 feet. Maximum decay activity exceeded 5000 pCi/g from 21 to 24 feet and 200 pCi/g at 20 feet. The cesium activity indicated from 0 feet to 3 feet is less than 6 pCi/g.

No Cobalt (Co-60) was encountered in the borehole. The plot track is present only for uniformity of the displayed data.

No Antimony (Sb-125) was encountered in the borehole. The plot track is present only for uniformity of the displayed data.

No Europium-154 (Eu-154) was encountered in the borehole. The plot track is present only for uniformity of the displayed data.

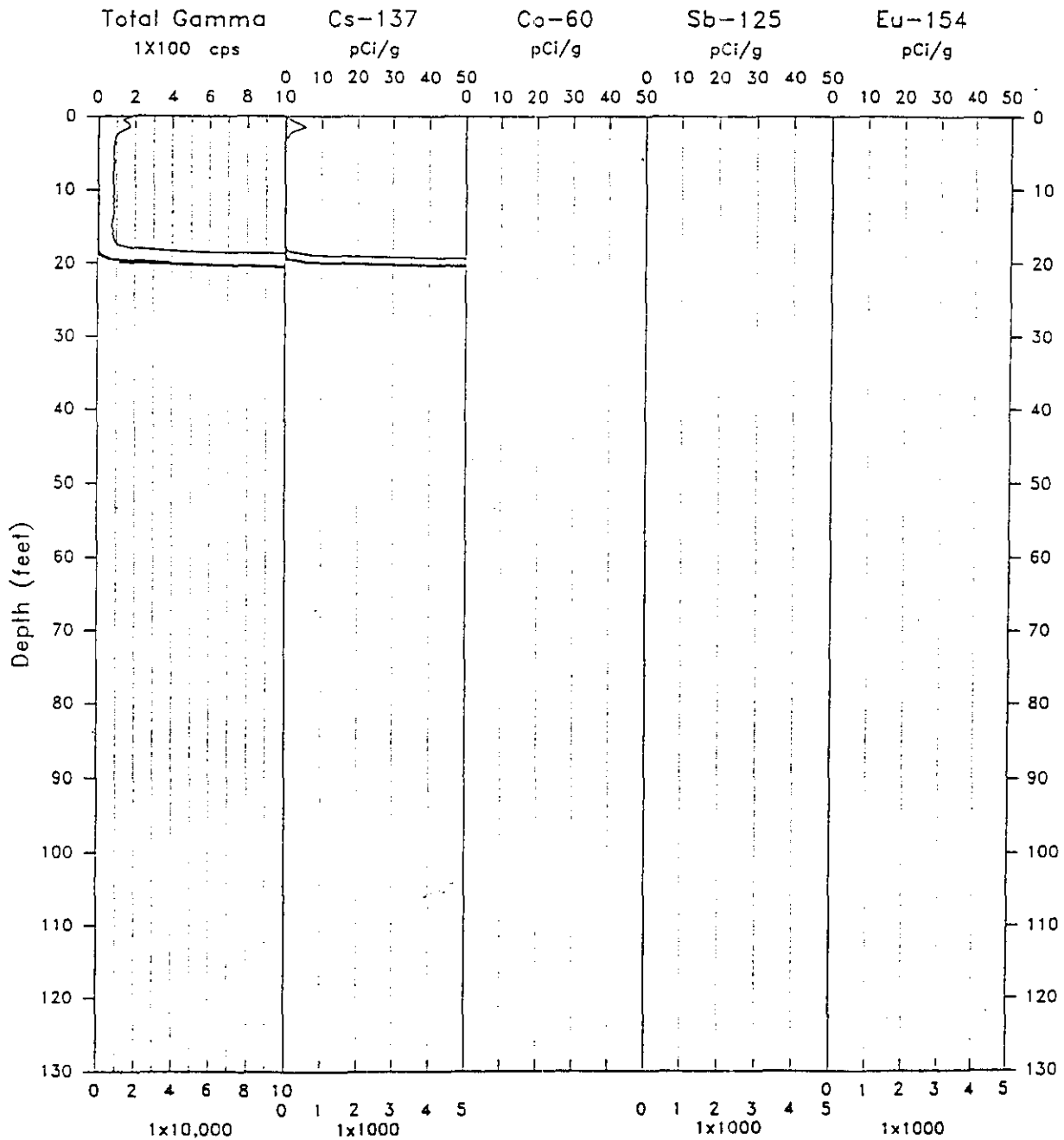
# RLS Spectral Gamma-Ray Borehole Survey

Project: Cone Penetrometer

Log Date: Sep 30, 92

Borehole: GP-05

Anal. Date: Oct 12,, 92



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**APPENDIX B**

**RLS Survey Data**

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Westinghouse Hanford Company  
 RLS Spectral Gamma-Ray Borehole Survey Log Header

Project: 200 BP - 1

Borehole	<u>CP-6</u>		
Coordinates	<u>NA N</u>	<u>NA W</u>	Feet (Hanford 200 Area)
Elevation	<u>NA</u> ft	Top of casing (Hanford 200 Area)	

## Borehole Environment Information

Borehole liquid depth <u>none</u> (ft) from zero (0.0) depth reference of log			
Casing size (in.)	Casing thickness (in.)	Top depth (ft)	Base depth (ft)
5	0.362	0	48.88

## RLS Passive Spectral Gamma Survey Information

Logging Engineers <u>R. V. Cram</u> <u>S. E. Kos</u>						
Log depth reference at zero (0.0) depth is <u>ground level</u>						
Log Date	Archive file names	Log mode	speed	Depth interval (ft)		
				Top	Base	Incr
Mar 05, 1993	CP06\A339	MSA	80sec RT	0	12.5	0.5
		Station 300sec		12.4		

MSA: Move-Stop-Acquire  
 RT: Real time

## Calibration and Analysis Information

RLS Calibration Date: Nov. 21, 1991	
Calibration Report: WHC-SD-EN-TRP-001	
Analyst Names: <u>W. F. Nicaise</u>	
Analysis Date: <u>Mar 10, 1993</u>	
Analysis Notes: _____	
Radionuclides Identified: <u>Natural only.</u>	

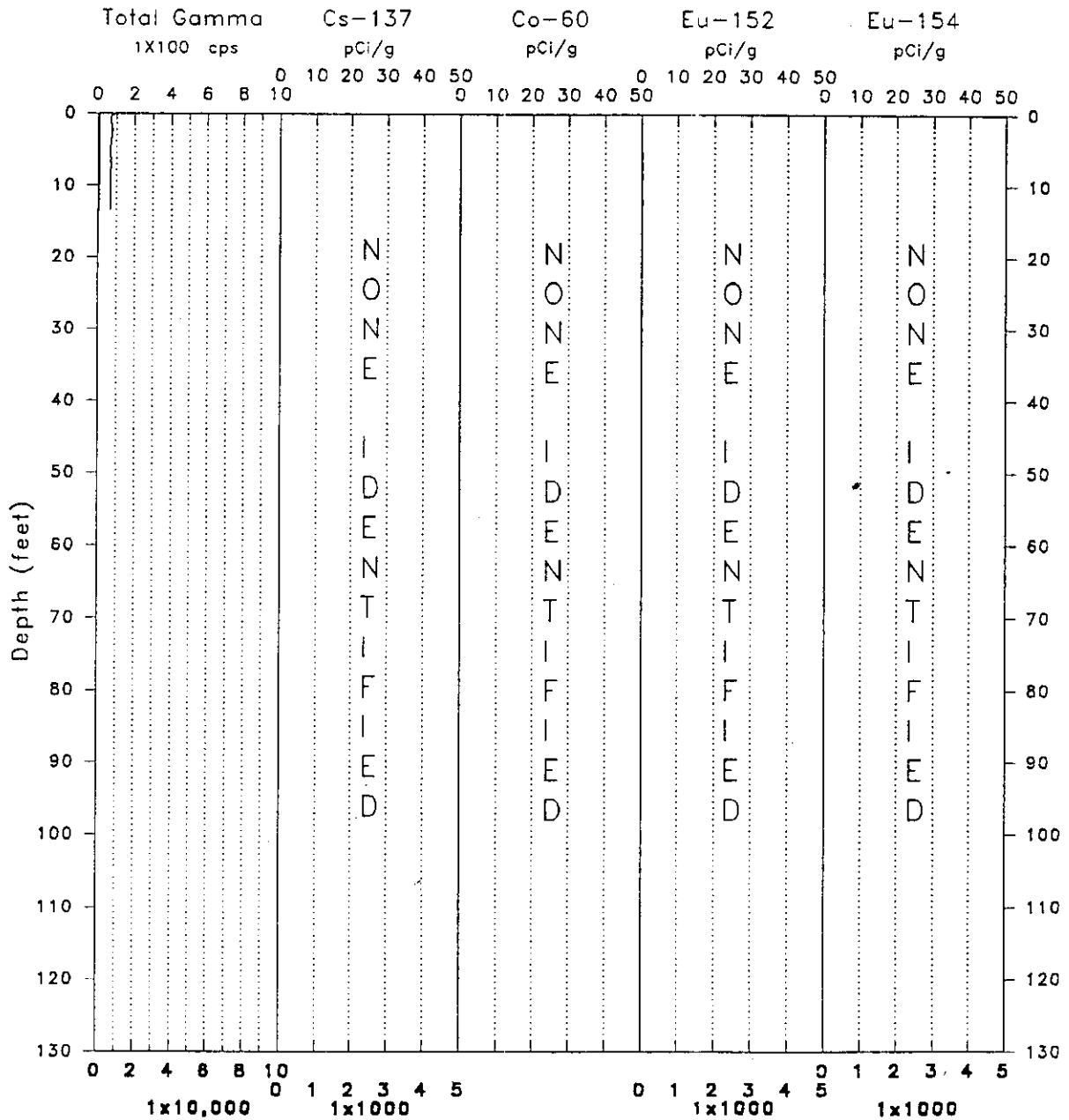
# RLS Spectral Gamma-Ray Borehole Survey

Project: 200-BP-1

Log Date: Mar 05, 1993

Borehole: CP-6

Anal. Date: Mar 10, 1993





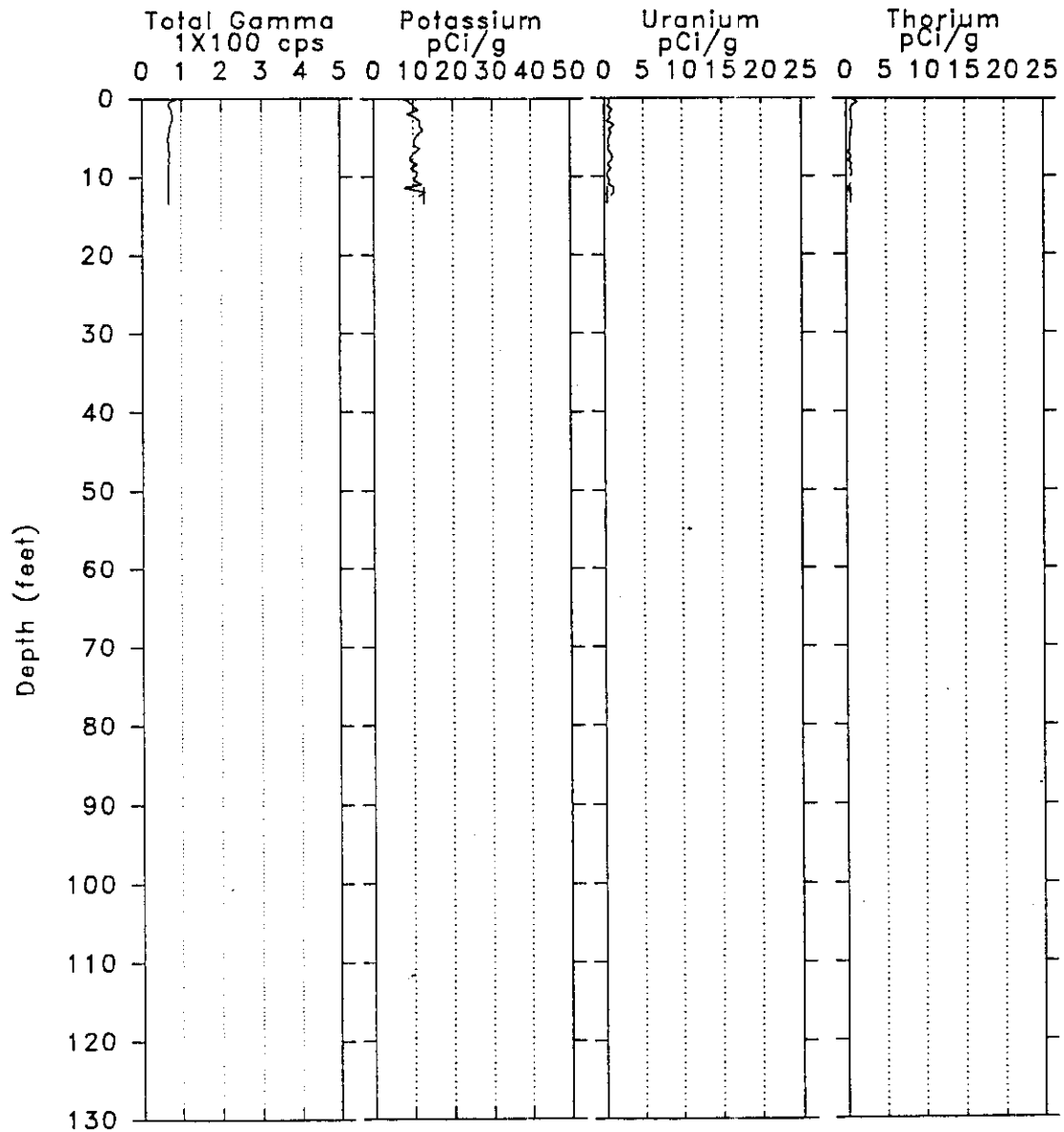
# RLS Spectral Gamma-Ray Borehole Survey

Project: 200-BP-1

Log Date : Mar 05, 1993

Borehole : CP-6

Anal Date: Mar10, 1993



RLS Borehole Survey Report

Borehole: CP-6

Casing	Depth: 48.88'	Size: 5"	Thickness: 0.362"
Water	Depth: none		
Survey	Depth: 0 - 12.5'	Date: 03/05/93	
	Stations: 12.4'		

**General Notes:**

The well was monitored at fixed intervals from 0 to 12.5 feet at fixed intervals of 0.5 feet, for real time counting intervals of 80 seconds. In addition the well was monitored at the fixed depth of 12.4 feet for a real time counting interval of 300 seconds. The only radionuclides detected were naturally occurring potassium, uranium, and thorium. These radionuclides were found to be present with calculated activities which are normal for Hanford soils, as is shown on the second plot. The first plot of man-made radionuclides, in which no radionuclides are shown detected, is included for uniformity of presentation only.

A slight elevation in the total gamma ray count rate can be observed at the surface level of the well. That the count rate drops immediately as the probe enters the subsurface indicates that the activity observed is not associated with the soil formation surrounding the well. Rather it must be a surface phenomenon, perhaps due to some slight surface contamination, or shine from a nearby above surface structure.

**Man-made Radionuclides:**

No man-made radionuclides observed.

Westinghouse Hanford Company  
RLS Spectral Gamma-Ray Borehole Survey Log Header

Project: 200 BP - 1

Borehole	CP-7		
Coordinates	NA N	NA W	Feet (Hanford 200 Area)
Elevation	NA ft	Top of casing (Hanford 200 Area)	

Borehole Environment Information

Borehole liquid depth <u>none</u> (ft) from zero (0.0) depth reference of log			
Casing size (in.)	Casing thickness (in.)	Top depth (ft)	Base depth (ft)
5	0.362	0	47.5

RLS Passive Spectral Gamma Survey Information

Logging Engineers <u>R. V. Cram</u> <u>S. E. Kos</u>						
Log depth reference at zero (0.0) depth is <u>ground level</u>						
Log Date	Archive file names	Log mode	speed	Depth interval (ft)		
				Top	Base	Incr
Mar 05, 1993	CP07\A340	MSA	80sec RT	0	43	0.5
Mar 05, 1993	CP07\A340	Station	300sec	43.5		

MSA: Move-Stop-Acquire  
RT: Real time

Calibration and Analysis Information

RLS Calibration Date: Nov. 21, 1991	
Calibration Report: WHC-SD-EN-TRP-001	
Analyst Names: <u>W. F. Nicaise</u>	
Analysis Date: <u>Mar. 24, 1993</u>	
Analysis Notes: _____	
Radionuclides Identified: <u>Cs-137</u>	

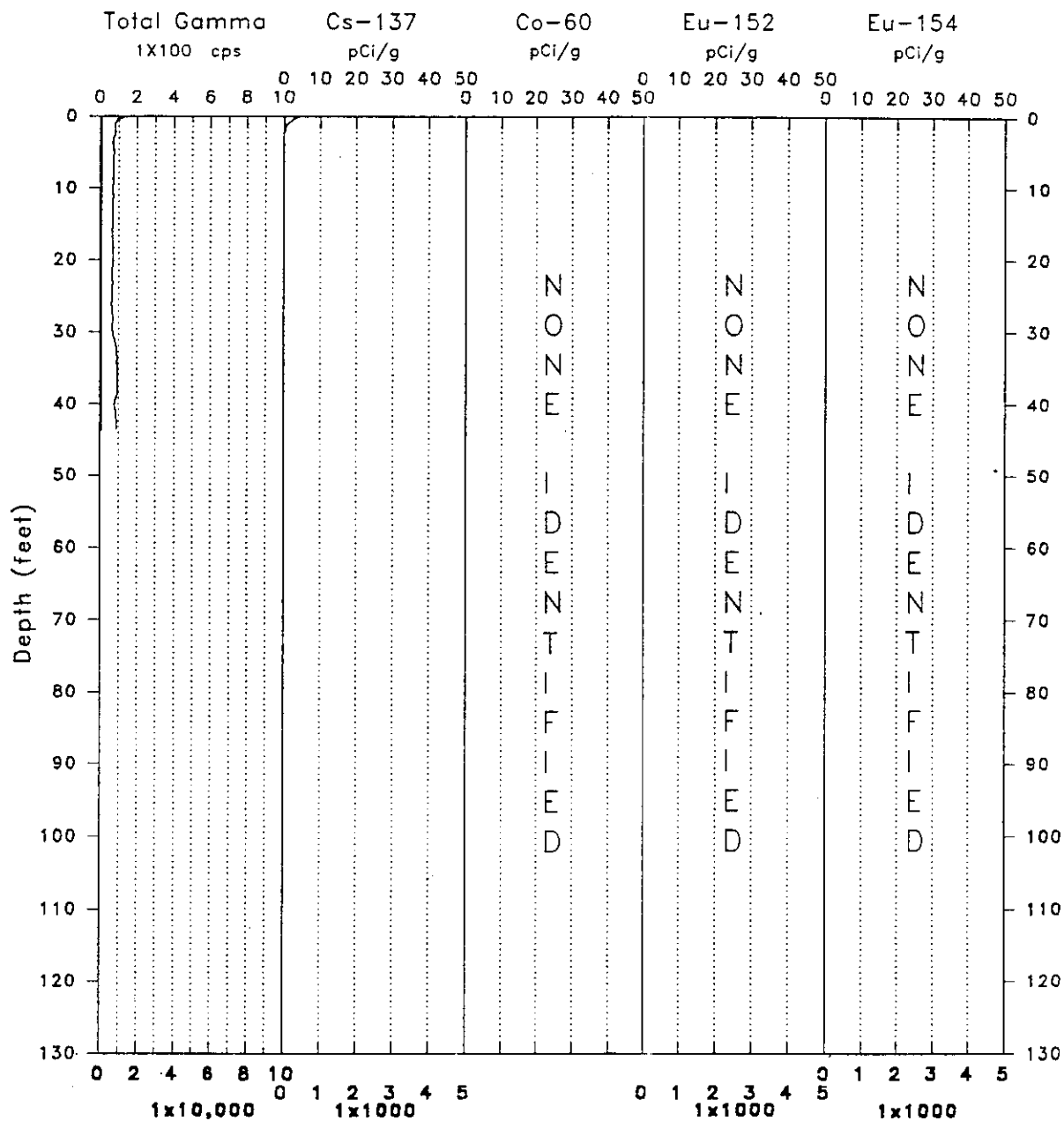
# RLS Spectral Gamma-Ray Borehole Survey

Project: 200 BP-1

Log Date: Mar 05, 1993

Borehole: CP-7

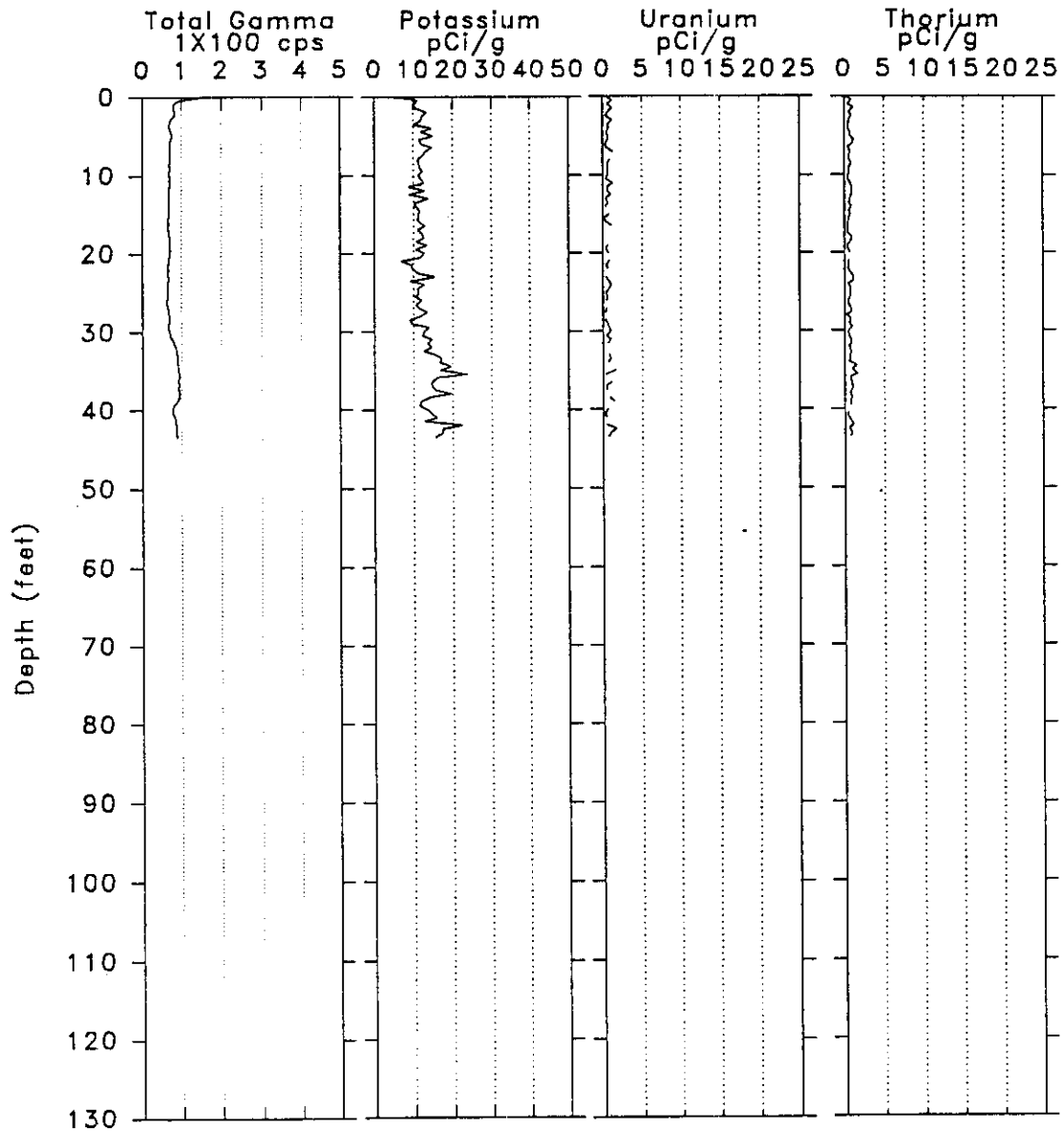
Anal. Date: Mar 24, 1993



# RLS Spectral Gamma-Ray Borehole Survey

Project: 200 BP-1  
Borehole : CP-7

Log Date : Mar 05, 1993  
Anal Date: Mar 24, 1993



RLS Borehole Survey Report

Borehole: CP-7

Casing	Depth: 47.5'	Size: 5"	Thickness: 0.362"
Water	Depth: none		
Survey	Depth: 0 - 43.5'	Date: 3/05/93	
	Stations: 43.5'		

**General Notes:**

The well was monitored at fixed intervals from 0 to 43.5 feet, in increments of 0.5 feet, for real counting periods of 80 seconds. The well was also monitored at the fixed depth of 43.5 feet for a real counting time of 300 seconds. As shown on the first plot the total gamma ray count rate is slightly elevated near ground level. This coincides with a similar region of activity which was observed due to the man-made radionuclide Cesium-137, from ground level to a depth of two feet. No other man-made radionuclides were observed. Although there is insufficient data at present to come to any definite conclusion regarding the source of this radionuclide, the depth profile of its activity is similar to that which would be expected for surface contamination which has diffused into undisturbed soil over time.

The naturally occurring radionuclides of potassium, uranium, and thorium are observed at activities which are normal for Hanford soils. These activities are shown on the second plot.

**Manmade Radionuclides:**

Cesium (Cs-137) was detected from ground level to two feet. The maximum calculated activity of 4 pCi/g occurred at the surface.

No Cobalt (Co-60) was detected. The template is presented for uniformity of presentation only.

No Europium (Eu-154) was detected. The template is presented for uniformity of presentation only.

No Europium (Eu-152) was detected. The template is presented for uniformity of presentation only.

WHC-SD-EN-TI-257, Rev. 0

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 RLS Spectral Gamma-Ray Borehole Survey Log Header

Project: 200 BP - 1

Borehole	CP-8		
Coordinates	NA N	NA W	Feet (Hanford 200 Area)
Elevation	NA ft	Top of casing (Hanford 200 Area)	

Borehole Environment Information

Borehole liquid depth <u>none</u> (ft) from zero (0.0) depth reference of log			
Casing size (in.)	Casing thickness (in.)	Top depth (ft)	Base depth (ft)
5	0.375	0	46.2

RLS Passive Spectral Gamma Survey Information

Logging Engineers <u>J. P. Kiesler</u> <u>S. E. Kos</u>			
Log depth reference at zero (0.0) depth is <u>ground level</u>			
Log Date	Archive file names	Log mode speed	Depth interval (ft) Top Base Incr
Mar 08, 1993	CP08\A342	MSA 80sec RT	0 18.5 0.5
		Station 300sec	18.7

MSA: Move-Stop-Acquire  
 RT: Real time

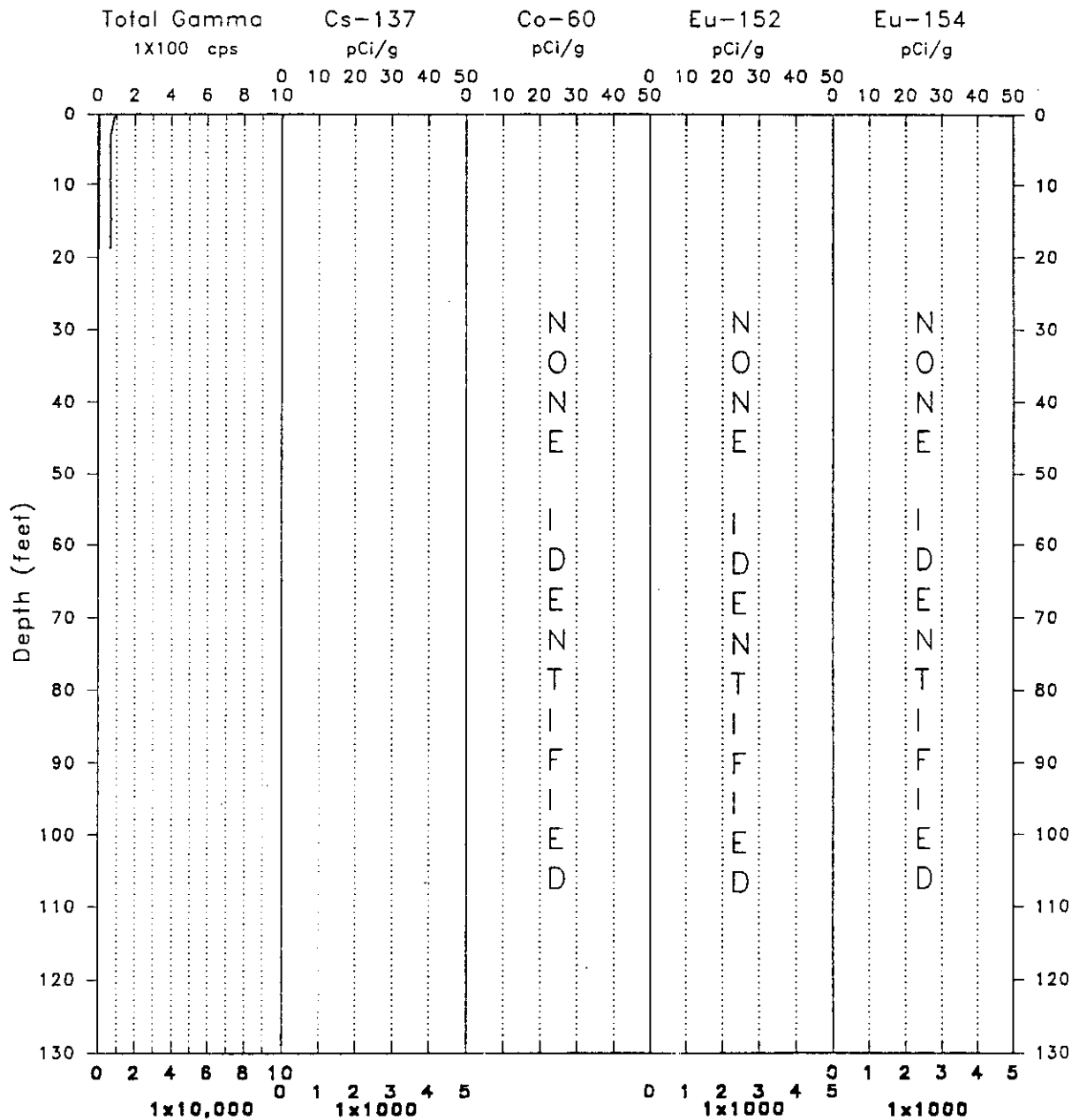
Calibration and Analysis Information

RLS Calibration Date: Nov. 21, 1991	
Calibration Report: WHC-SD-EN-TRP-001	
Analyst Names: <u>W. F. Nicaise</u>	<u>R. K. Price</u>
Analysis Date: <u>Mar. 15, 1993</u>	
Analysis Notes: _____	
Radionuclides Identified: <u>Cs-137</u>	

# RLS Spectral Gamma-Ray Borehole Survey

Project: 200 BP-1  
Borehole: CP-8

Log Date: Mar 08, 1993  
Anal. Date: Mar 15, 1993

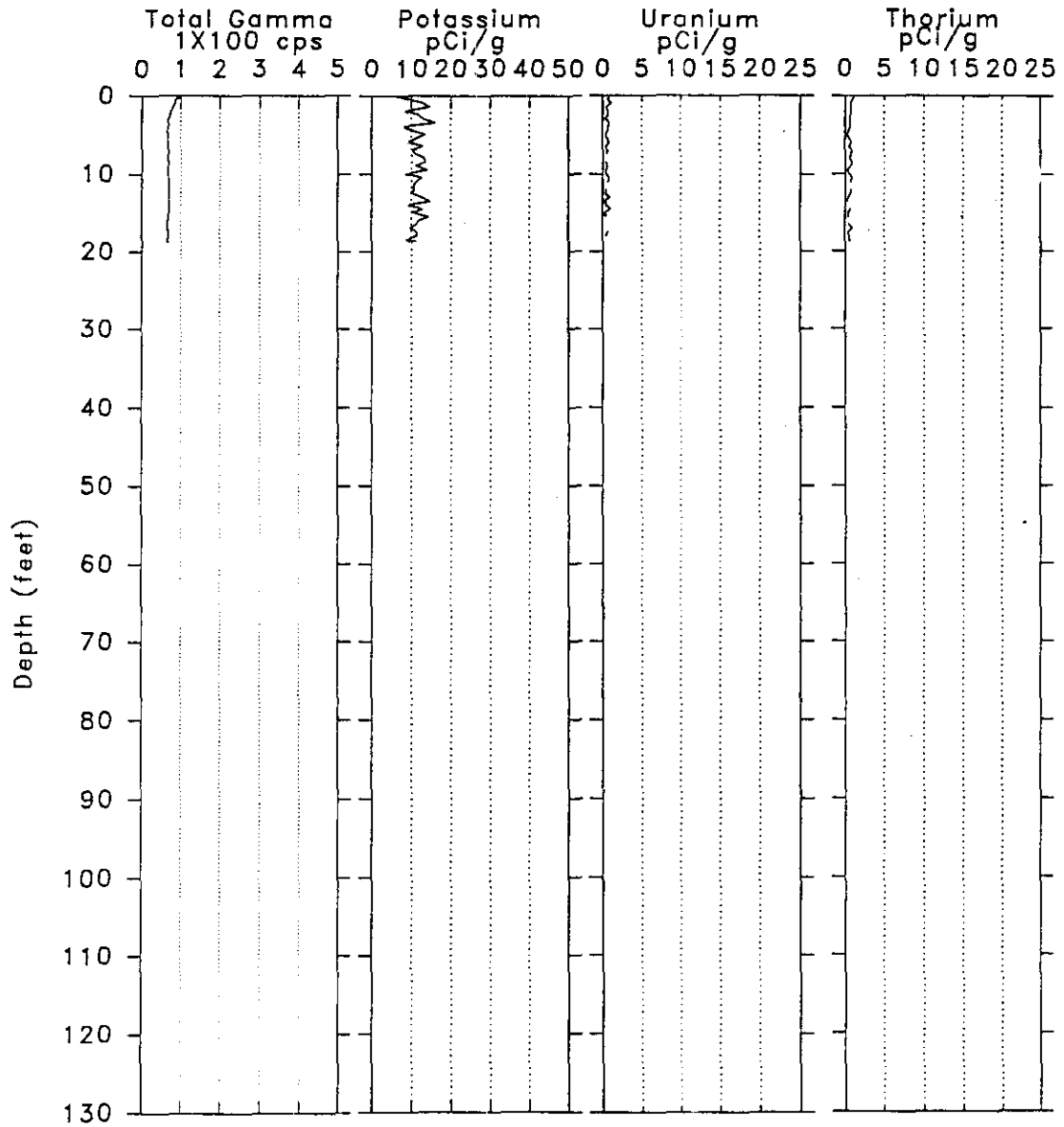




# RLS Spectral Gamma-Ray Borehole Survey

Project: 200-BP-1  
Borehole : CP-8

Log Date : Mar 08, 1993  
Anal Date: Mar 15, 1993



RLS Borehole Survey Report

Borehole: CP-8

Casing	Depth: 46.2'	Size: 5"	Thickness: 0.375"
Water	Depth: none		
Survey	Depth: 0 - 18.7'	Date: 3/08/93	
	Stations: 18.7'		

**General Notes:**

It was planned to monitor the well at fixed intervals from 0 to 43 feet at increments of 0.5 feet, for real time counting intervals of 80 seconds. However the casing was kinked such that it was not possible to monitor the well with the RLS borehole sonde below a depth of 18.7 feet. An additional measurement was taken at 18.7 feet for a real time counting interval of 300 seconds.

The only man-made radionuclide observed is Cesium-137, which was found to be present in the first one half foot of soil. The calculated activity of this radionuclide varied from approximately 0.7 pCi/g at the surface to 0.2 pCi/g at 0.5 feet. Although there is insufficient data at present to come to any definite conclusions regarding this radionuclide, the depth profile of the activity is similar to that which would be expected for surface contamination which has diffused into undisturbed soil over time. The activity profile is shown on the first plot.

The naturally occurring radionuclides of potassium, uranium, and thorium are observed at activities which are normal for Hanford soils. These activities are shown on the second plot.

**Manmade Radionuclides:**

Cesium (Cs-137) was detected from zero to 0.5 feet. The maximum calculated activity of this radionuclide is less than 1 pCi/g, occurring at the surface.

No Cobalt (Co-60) was detected. The template is presented for uniformity of presentation only.

No Europium (Eu-154) was detected. The template is presented for uniformity of presentation only.

No Europium (Eu-152) was detected. The template is presented for uniformity of presentation only.

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RLS Spectral Gamma-Ray Borehole Survey Log Header

Project: 200 BP - 1

Borehole	<u>CP-9</u>		
Coordinates	<u>NA N</u>	<u>NA W</u>	Feet (Hanford 200 Area)
Elevation	<u>NA</u> ft	Top of casing (Hanford 200 Area)	

## Borehole Environment Information

Borehole liquid depth <u>none</u> (ft) from zero (0.0) depth reference of log			
Casing size (in.)	Casing thickness (in.)	Top depth (ft)	Base depth (ft)
5	0.375	0	49.2

## RLS Passive Spectral Gamma Survey Information

Logging Engineers <u>R. V. Cram</u> <u>S. E. Kos</u>					
Log depth reference at zero (0.0) depth is <u>ground level</u>					
Log Date	Archive file names	Log mode	speed	Depth interval (ft)	
				Top	Base      Incr
Mar 10, 1993	CP09\A343	MSA	80sec RT	0	46.5    0.5
Mar 10, 1993	CP09\A343	Station	300sec	32', 46.5'	

MSA: Move-Stop-Acquire  
RT: Real time

## Calibration and Analysis Information

RLS Calibration Date: Nov. 21, 1991	
Calibration Report: WHC-SD-EN-TRP-001	
Analyst Names: <u>W. F. Nicaise</u>	<u>R. K. Price</u>
Analysis Date: <u>Mar. 18, 1993</u>	
Analysis Notes: _____	
Radionuclides Identified: <u>Cs-137</u>	

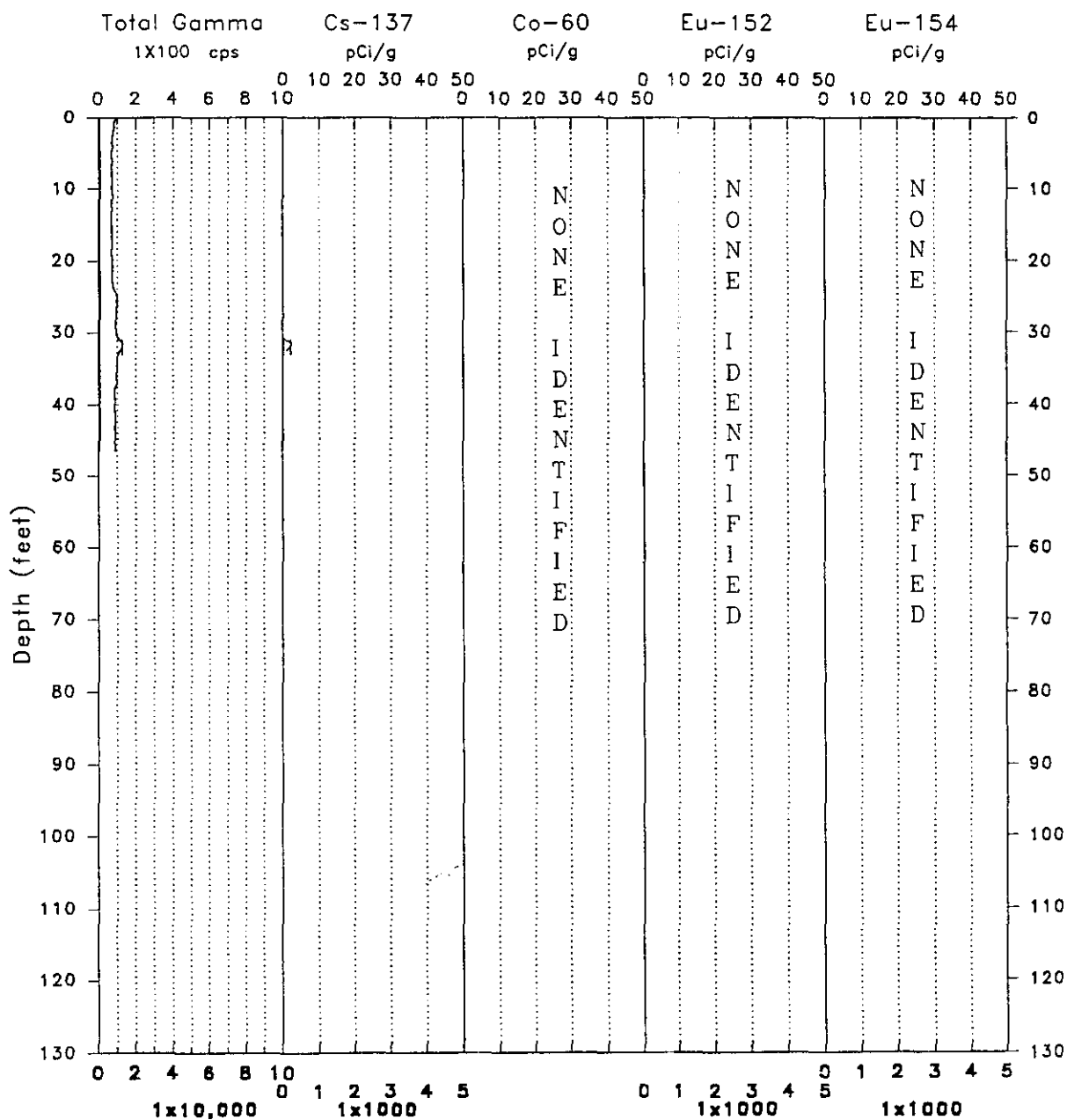
# RLS Spectral Gamma-Ray Borehole Survey

Project: 200 BP-1

Log Date: Mar 10, 1993

Borehole: CP-9

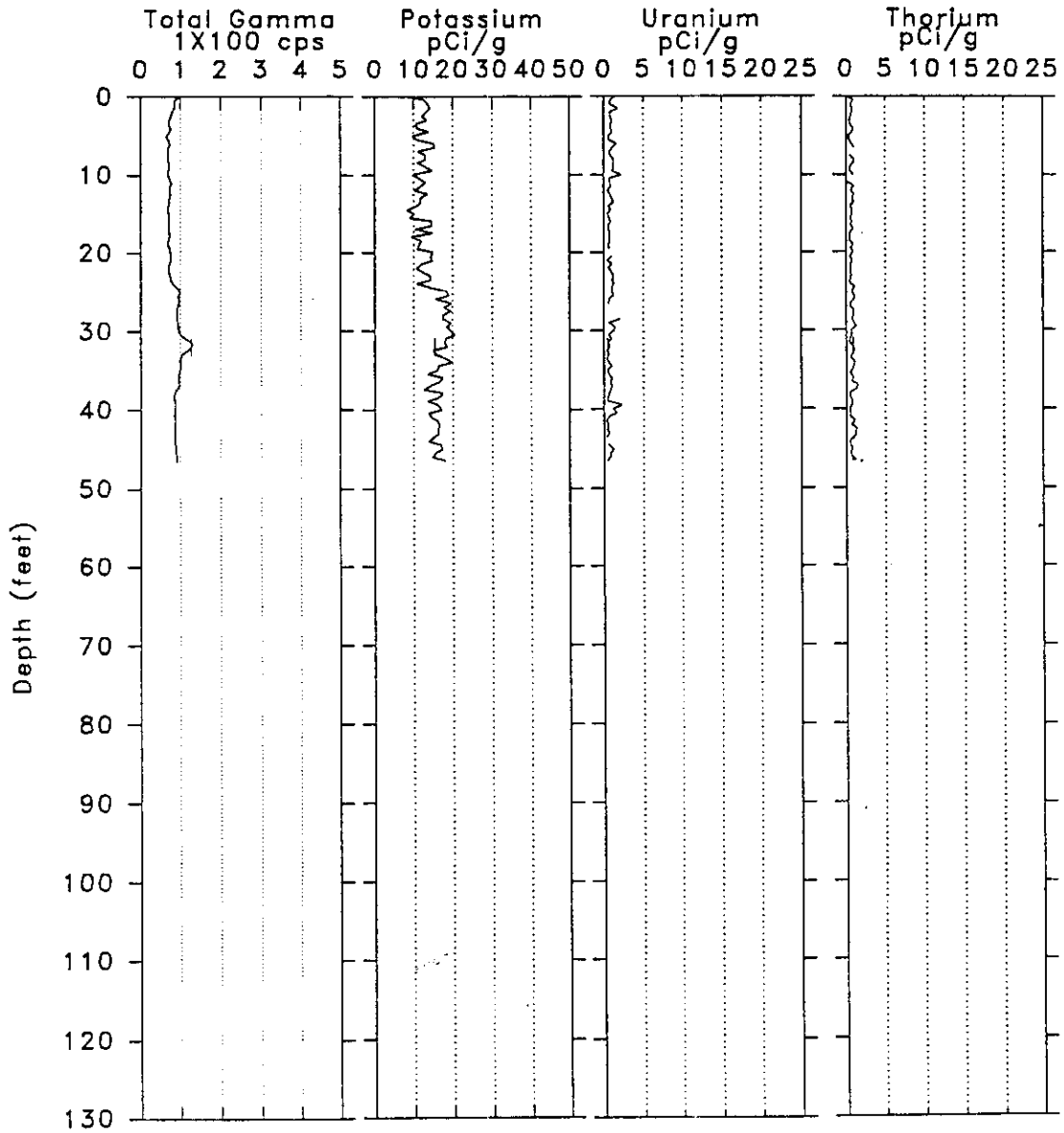
Anal. Date: Mar 18, 1993



## RLS Spectral Gamma-Ray Borehole Survey

Project: 200 BP-1  
Borehole : CP-9

Log Date : Mar 10, 1993  
Anal Date: Mar 18, 1993



RLS Borehole Survey Report

Borehole: CP-9

Casing	Depth: 49.2'	Size: 5"	Thickness: 0.375"
Water	Depth: none		
Survey	Depth: 0 - 46.5'	Date: 03/10/93	
	Stations: 32', 46.5'		

**General Notes:**

The well was monitored at fixed intervals from 0 to 46.5 feet, in increments of 0.5 feet, for real counting periods of 80 seconds. The well was also monitored at the fixed depths of 32 and 46.5 feet for real counting times of 300 seconds. The total gamma count rate shows a slightly elevated activity in the range from 31 to 33 feet. This coincides with a similar region of activity which was observed due to the man-made radionuclide Cesium (Cs-137) centered at a depth of about 32 feet. No other man-made radionuclides were observed. These data are shown on the first plot. The naturally occurring radionuclides potassium, uranium, and thorium were also observed at activities which are normal for Hanford soils. These activities are shown on the second plot.

**Man-made Radionuclides:**

Cesium (Cs-137) was detected from 31 to 33 feet. The maximum concentration of 3 pCi/g occurred at a depth of 32 feet.

No Cobalt (Co-60) was detected. The template is presented for uniformity of presentation only.

No Europium (Eu-154) was detected. The template is presented for uniformity of presentation only.

No Europium (Eu-152) was detected. The template is presented for uniformity of presentation only.

**APPENDIX C**

**RLS Data for Other Holes in the Vicinity of Crib 216-B-57**

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RLS Spectral Gamma-Ray Borehole Survey Log Header

Project: 200-BP-1, 216-B-47 Crib

Borehole	<u>299-E33-05</u>		
Coordinates	<u>46,352</u> N	<u>53,523</u> W	Feet (Plant 200 E)
Elevation	<u>632.04</u> feet	Top of Casing (Plant 200 E)	

Borehole Environment Information

Borehole Fluid Depth <u>224</u> (Feet) from Zero (0.0) Depth Reference of Log			
Casing Size I.D. (inch)	Casing Thickness (inch)	Top Depth (feet)	Base Depth (feet)
8	0.312	0.0	236.0
4	0.188	0.0	214.0

RLS Passive Spectral Gamma Survey Information

Logging Engineers <u>R. V. Cram</u> <u>A. Pearson</u>					
Log Depth Reference at Zero (0.0) depth is <u>Ground Level</u>					
Log Date	Archive File Names	Log Mode, Speed	Depth Interval (feet)		
			Top	Base	Incr
Sept 12, 91	H2E3305\A072	FIXED 1.5 fpm	0.0	132.0	0.5
Sept 18, 91	H2E3305\A075	FIXED 0.8 fpm	0.0	106.0	0.5
Sept 18, 91	H2E3305\A076	FIXED 0.8 fpm	98.0	173.0	0.5
Sept 18, 91	H2E3305\A077	FIXED 0.8 fpm	150.0	236.0	0.5

FIXED: Fixed velocity of Cable Speed: fpm: Feet per minute

Calibration and Analysis Information

RLS Calibration Date: Nov 21, 1991	
Calibration Report: WHC-SD-EN-TRP-001	
Analyst Names: <u>J. P. Kiesler</u>	<u>R. K. Price</u>
Analysis Date: <u>Sept 01, 1992</u>	
Analysis Notes: Two survey scans to 132' demonstrate good repeatability	
Radionuclides identified: <u>Cs-137, Co-60, Sb-125</u>	

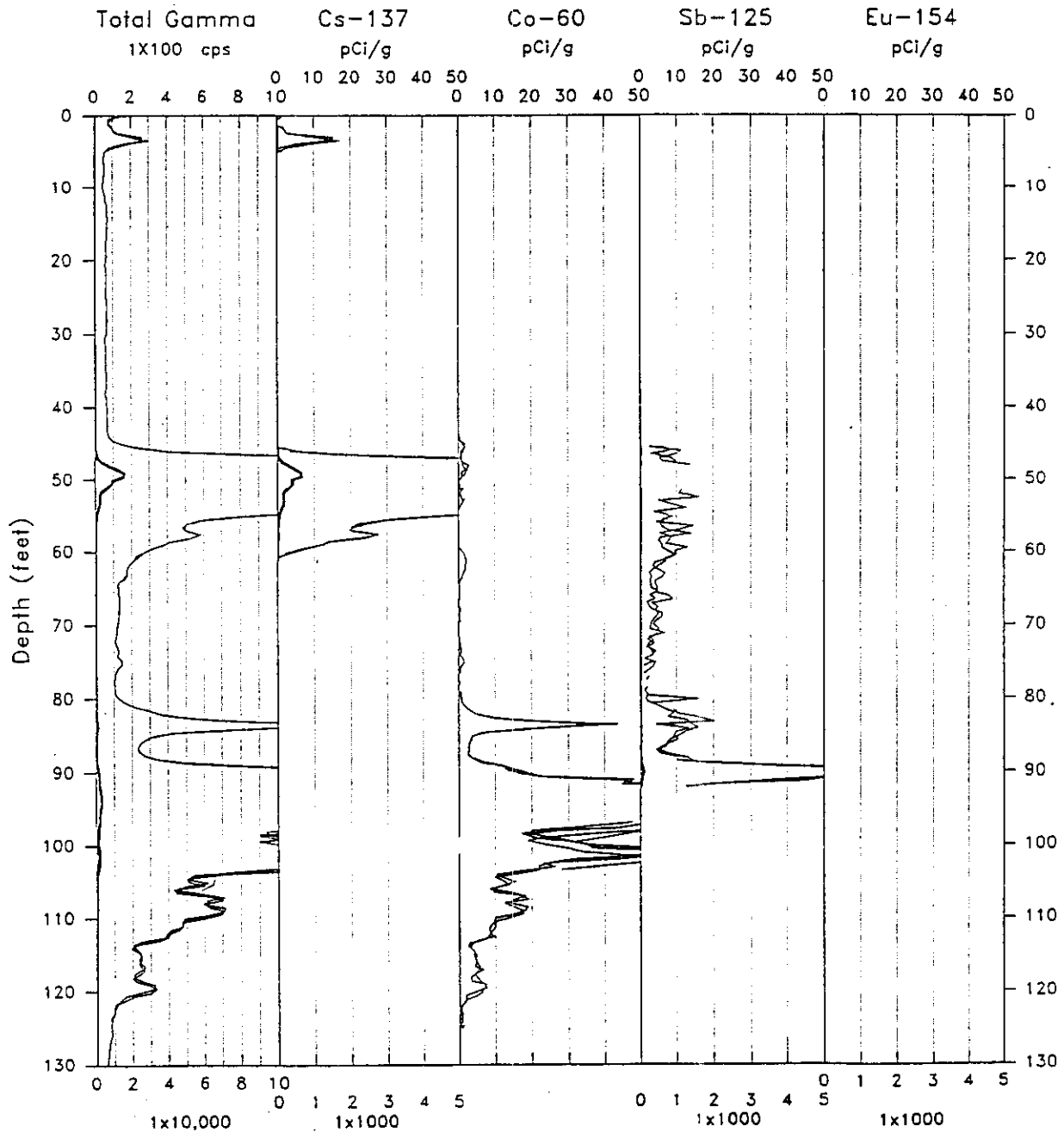
# RLS Spectral Gamma-Ray Borehole Survey

Project: 200-BP-1

Log Date: Sept 18, 91

Borehole: 299-E33-5

Anal. Date: Sep 1, 92



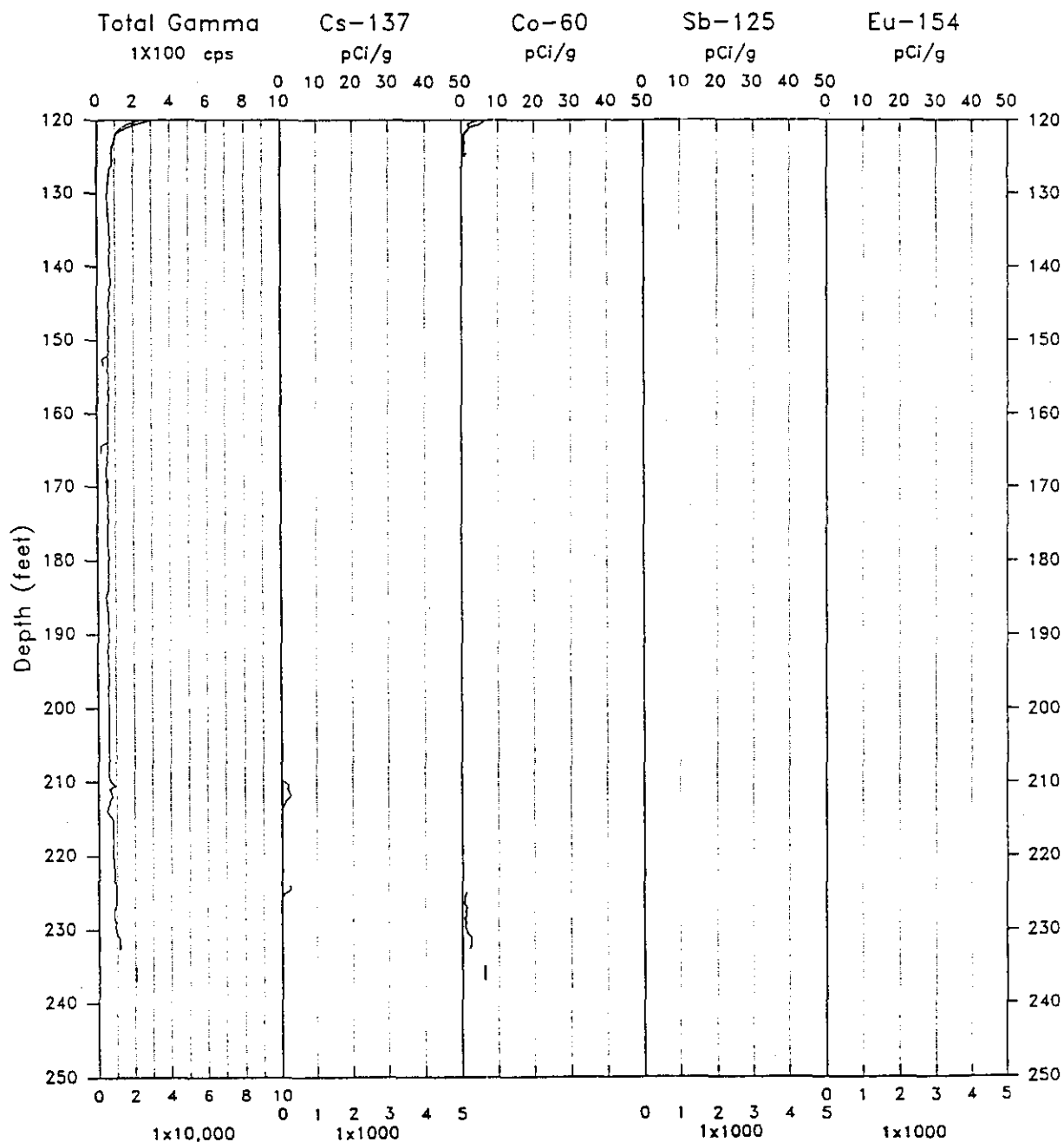
# RLS Spectral Gamma-Ray Borehole Survey

Project: 200-BP-1

Log Date: Sep 18, 91

Borehole: 299-E33-5

Anal. Date: Sep 1, 92



# RLS Borehole Survey Report

299-E33-05 216-B-47 Crib

Casing	Depth: 234 ft.	Size: 8 in.	Thickness: 0.313 in.
	Depth: 214 ft.	Size: 6 in.	Thickness: 0.188 in.
Water	Depth: 224 ft.		
Survey	Depth: 0 - 132 ft.	Date: 9/12/91	
	0 - 106 ft.	9/18/91	
	98 - 173 ft.	9/18/91	
	150 - 236 ft.	9/18/91	

## General Notes:

The data are plotted on two pages. The survey data from 120 ft to 130 ft are plotted on both pages.

The first 130 ft. were surveyed at two logging speeds to check system repeatability. The first log run (0 to 132 ft ) was incorrectly started at the top of the casing (2 ft above ground level) therefore a 2-ft. correction was applied for plotting. During the second survey, field problems forced restart of the computer program and reentry of the detector depth. The tool was repositioned at 98 feet for the third set of data. An overlap interval from 98 ft to 106 ft between data sets two and three identified a 1-ft. error then the depth was reentered. A minus 1-ft correction has been applied to the third data set (98 to 173 ft.) for the log plot.

The maximum calibrated casing correction of 0.40 in. was applied to the survey data. The computed activity for data recorded through multiple casing strings will be underestimated.

The total gamma activity did not exceed 17,000 cps in the borehole survey.

## Man-made Radionuclides:

Cesium (Cs-137) was encountered in three intervals in the borehole: 0-7 ft., 48-63 ft and 210-226 ft. The cesium decay activity exceeded 200 pCi/g from 50 ft to 54 ft.

Cobalt (Co-60) was encountered in two intervals in the borehole from 46 to 127 ft. and from 225 to 236 ft. The maximum decay activity detected was 90 pCi/g to 93 ft.

Antimony (Sb-125) was encountered in the borehole from 45 ft to 92 ft. The maximum decay activity detected was 70 pCi/g at 90 ft.

No Europium-154 (Eu-154) was encountered in the borehole. The plot track is present only for uniformity of the displayed data.

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**RLS Spectral Gamma-Ray Borehole Survey Log Header**

Project: 200 AAMS, 216-B-57 Crib

Borehole	<u>299-E33-24</u>		
Coordinates	<u>42.260</u> N	<u>53.790</u> W	Feet (Plant 200 W)
Elevation	<u>638.03</u> feet	Top of Casing (Plant 200 W)	

**Borehole Environment Information**

Borehole Fluid Depth <u>232.5</u> (Feet) from Zero (0.0) Depth Reference of Log			
Casing Size I.D. (inch)	Casing Thickness (inch)	Top Depth (feet)	Base Depth (feet)
8.0	0.327	0.0	249.7

**RLS Passive Spectral Gamma Survey Information**

Logging Engineers <u>R. V. Cram</u> <u>S. E. Kos</u>					
Log Depth Reference at Zero (0.0) depth is <u>Ground Level</u>					
Log Date	Archive File Names	Log Mode, Speed	Depth Interval (feet)		
			Top	Base	Incr
July 13, 92	H2E3324\A204	MSA 80sec LT	0.0	75.0	0.5
July 14, 92	H2E3324\A205	MSA 80sec LT	73.0	191.5	0.5
July 15, 92	H2E3324\A206 A206"A"	MSA 80sec LT	190.0 28.0	246.7 53.0	0.5 0.5

MSA: Move-Stop-Acquire LT: Live Time

**Calibration and Analysis Information**

RLS Calibration Date: <u>Nov 21, 1991</u>	
Calibration Report: <u>WHC-SD-EN-TRP-001</u>	
Analyst Names: <u>J. P. Kiesler</u>	<u>R. K. Price</u>
Analysis Date: <u>August 3, 1992</u>	
Analysis Notes: <u>A206"A" is rerun of 28.0 to 53.0 feet with pb shield</u>	
Radionuclides identified: <u>Cs-137, Co-60</u>	

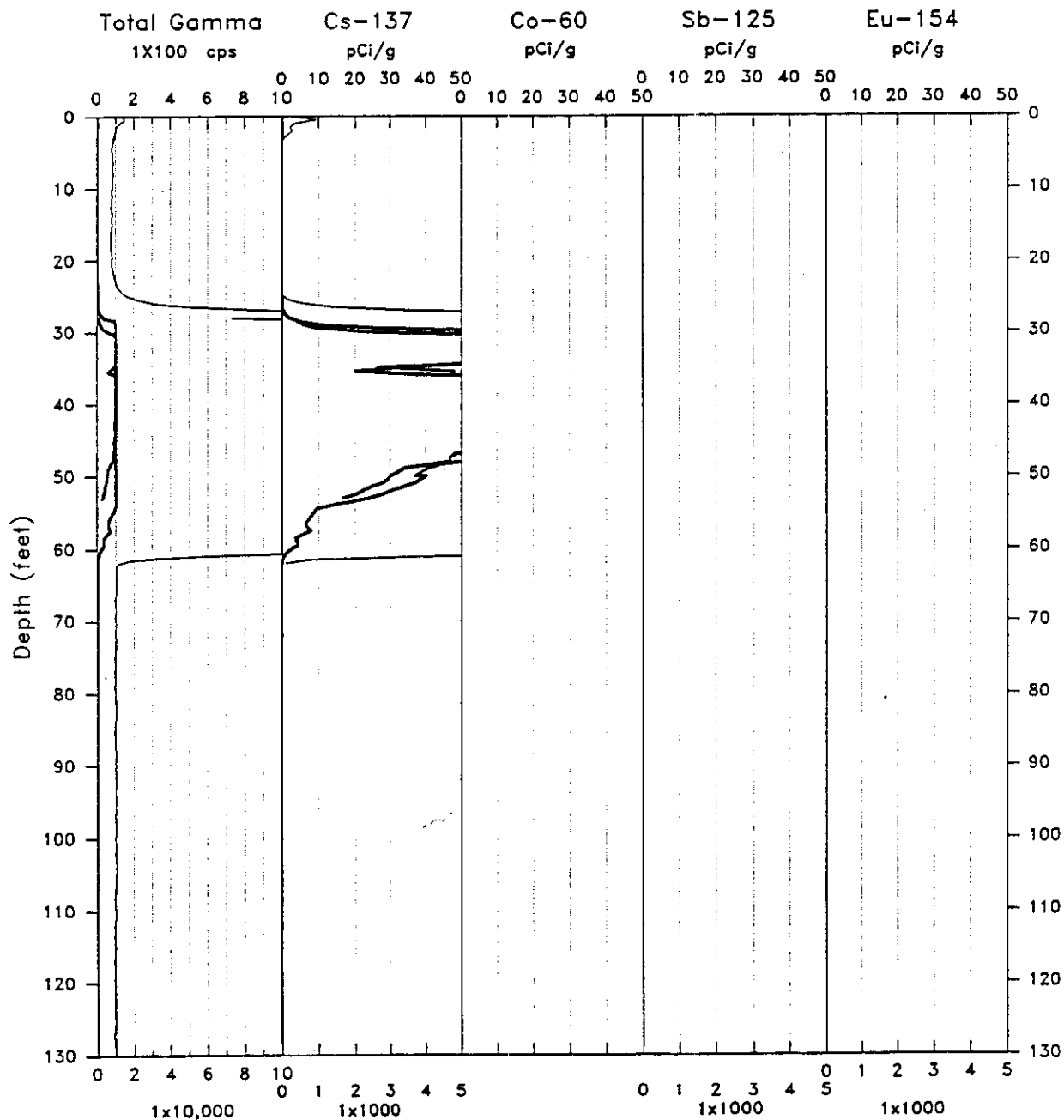
# RLS Spectral Gamma-Ray Borehole Survey

Project: 200-BP-1 Remediation

Log Date: Jul 13, 92

Borehole: 299-E33-24

Anal. Date: Aug 3, 92



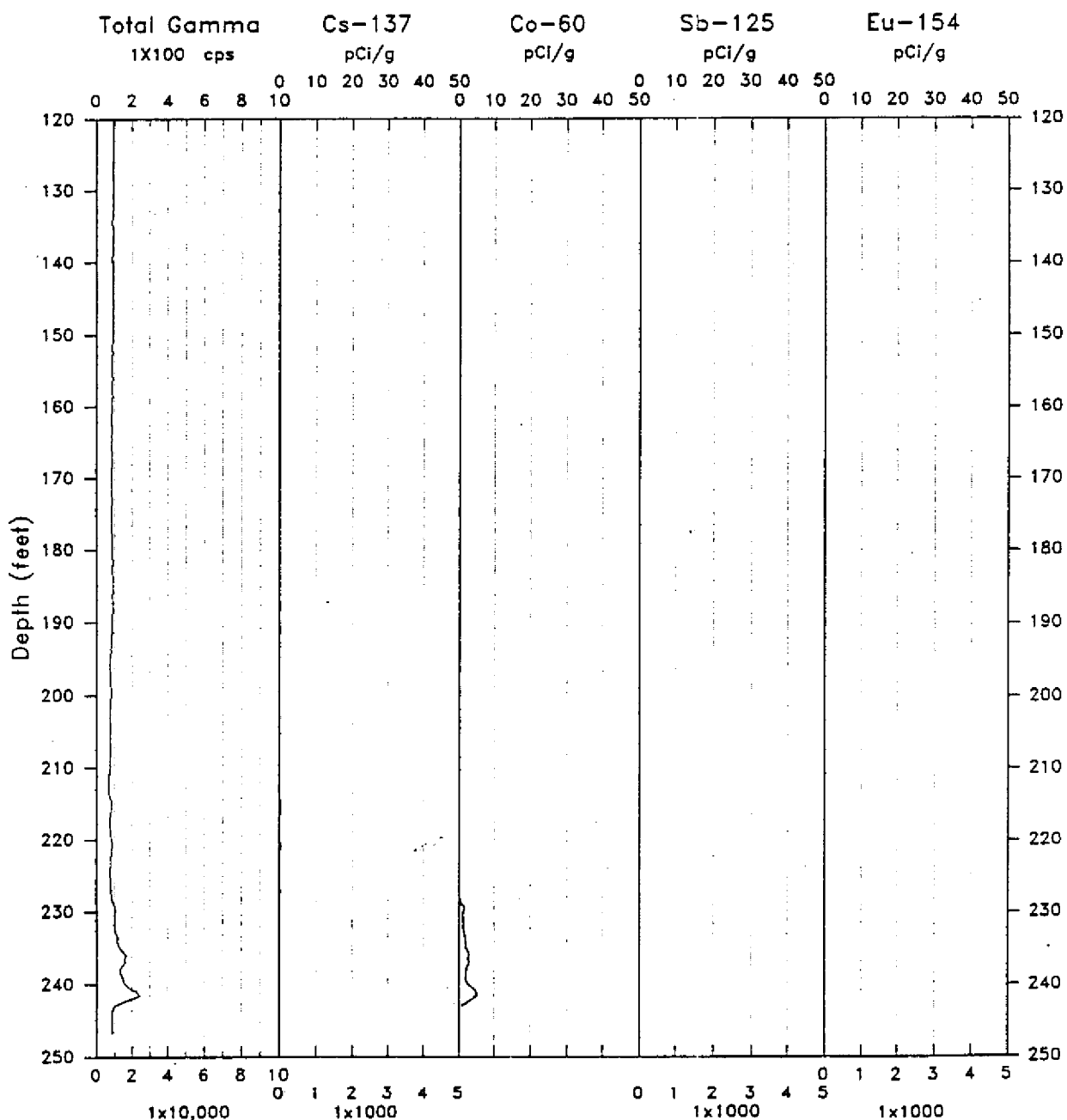
# RLS Spectral Gamma-Ray Borehole Survey

Project: 200-BP-1 Remediation

Log Date: Jul 13, 92

Borehole: 299-E33-24

Anal. Date: Aug 3, 92



RLS Borehole Survey Report

299-F33-24      216-B-57 Crib

Casing	Depth: 249.7'	Size: 8"	Thickness: 0.327"
Water	Depth: 232.5'		
Survey	Depth: 0 - 75'	Mode: MSA 80 sec	Date: 7/13/92
	Depth: 73 - 191'	Mode: MSA 80 sec	Date: 7/14/92
	Depth: 190 - 246'	Mode: MSA 80 sec	Date: 7/15/92
	28 - 53'	Mode: MSA 80 sec	(Lead Shield)

**General Notes:**

The maximum total gamma count rate reported by the data reduction program "LGCALC" prior to Aug 20, 1992 was 10,000 cps. Total gamma activity from 30 feet to 55 feet exceeded the plotted maximum of 10,000 cps.

Both standard configuration and lead shield logging configuration data surveys are plotted together. The numeric data values of the Total Gamma plot for the two configurations will not produce identical values. No Total Gamma correction for the gamma-ray attenuation from the lead shield has been established.

Computed activity for the man-made radionuclides for both logging configurations agree within the 2-sigma uncertainties.

**Man-made radionuclides:**

Cesium (Cs-137) was encountered in three zones in the borehole. The depth intervals are: surface to 3 feet, 25 to 63 feet, and 204 to 245 feet. The cesium decay activities exceeded 200 pCi/g from 28 feet to 60 feet. The decay activity exceeded 5000 pCi/g from 30 to 35 feet and from 36 to 47 feet.

Cobalt (Co-60) was observed from 228 feet to 243 feet. The maximum decay activity detected was 5 pCi/g at 241 feet.

No Antimony (Sb-125) was encountered in the borehole. The plot track is present only for the uniformity of the displayed data.

No Europium-154 (Eu-154) was encountered in the borehole. The plot track is present only for the uniformity of the displayed data.



## APPENDIX D

### The RLS System

The Radionuclide Logging System (RLS) is a passive, high-resolution, gamma-ray energy-spectrum, in-borehole logging system. The system utilizes a semi-conducting crystal of high-purity germanium (HPGe); the crystal is cooled during logging with liquid nitrogen, and an electrical potential is imposed across the crystal. Gamma-ray interactions with the crystal produces sharp electrical pulses with energies correlative to the energies of the impinging gamma rays, resulting in excellent gamma-ray energy resolution. This in turn, allows for the direct identification of the radionuclides from which those gamma rays were emitted. With appropriate calibration, concentrations of the gamma-ray-emitting radionuclides surrounding the borehole can be assayed, as well as identified.

The logging cable equipped on the RLS was specifically designed for the system. It suspends the detector in the well, conducts power to the detector, receives electrical signals from the detector, and provides the conduit for venting the liquid nitrogen component of the detector. Errors in the depth-measuring system of the RLS are mainly related to cable stretch, cable and sheave wheel contact, and electronic encoding components. The recorded depth of the detector is estimated to be accurate to 98.5 percent, with a precision (repeatability) of 99 percent. Comparisons with drilling measurements, other logging equipment, and secondary measuring systems have verified the accuracy. An upgrade in the logging cable and measuring system is being investigated.

There are two configurations in which the logging sonde can be used. One is the as-built state (standard) and the other (alternate) is with an external "shield" (gamma-ray absorbing material) placed around it.

The standard logging configuration optimizes the counting system for detecting low decay activities of radioelements. The RLS has frequently detected man-made radioelement activities of 0.3 pCi/g for nuclides emitting gamma rays having energies greater than 500 keV and the number of gamma-rays emitted per decay being at least one for each two decays (greater than 50 percent). The maximum decay activity the RLS has detected is about 10,000 pCi/g in this standard configuration.

The alternate logging configuration at present employs a lead shield and changes the counting system to maximize the count rate. Configuring the counting system to maximize the count rate compromises its ability to detect radioelements at low decay activities (concentrations). The RLS has frequently detected man-made radioelement activities exceeding 33,000 pCi/g in this shielded configuration. The alternate logging configuration was not employed for the surveys included in this report because of the low count rates encountered.

### Limitations to the Radioelement Analyses

The borehole surveys presented in this report have all been analyzed using the calibration data acquired in November 1991. Calculation of the calibration factors used in data reduction depend on the calibration data and on nuclear data (half-lives, branching ratios, number of gamma-rays per decay) for the particular nuclide. All of the nuclear data were taken from Erdtmann and Soyka (1979).

Borehole-environment correction factors have been determined for steel casing and water in the borehole. Correction factors for other borehole configurations have not been investigated. Borehole configurations for which no correction is available include: (1) grout between multiple casing strings, (2) formation seals containing bentonite, sand, or grout behind the casing, and (3) drilling mud remaining inside the borehole during logging. The calculated decay activity for man-made radionuclides will be underestimated for boreholes with these configurations.

Energy-dependent casing corrections have been established for steel casing thicknesses up to 0.40 inches. Corrections for casings of different materials and/or cumulative thicknesses greater than 0.40 inches have not been calculated and therefore cannot be used in the data reduction.

The calibration data were recorded with the detector centered in calibration zones that are uniform in density, water content, and gamma-ray source material. The dimensions of each zone are large enough that the detector always responded as though surrounded by a medium of infinite extent. Therefore, the use of the calibration results to calculate nuclide activity carries the assumption that the nuclides in the logged formation are also distributed in thick uniform layers. Gamma-ray sources are not normally distributed in the earth in thick uniform layers. Source inhomogeneities are reflected to some degree by the fluctuations in the amplitudes of the log traces. A factor called the "vertical spacial resolution" quantifies the correlation between (1) the amplitude of the log fluctuation and the depth interval over which it extends, and (2) the intensity of the corresponding gamma-ray source and the thickness of the zone in which the source is embedded. The vertical spatial resolution of the RLS HPGe logging system is scheduled for investigation.

Radionuclide decay activities are determined from the net area of the gamma-ray peaks. Radioelements, such as strontium-90, which do not emit a gamma ray when they decay will not be identified or quantified by the spectral analysis performed for this report. The decay of strontium-90 results in a high-energy beta particle that can excite surrounding elements to emit photon radiation that can be identified by the HPGe detector. This type of radiation is called "bremsstrahlung" radiation. A method to obtain estimates of the concentrations of strontium-90 is under consideration.

# DISTRIBUTION SHEET

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		ECN No. N/A

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